Heavy-Duty Diesel Vehicle Emissions Modeling in California's EMFAC Model

Mobile Source Analysis Branch
Air Quality Planning and Science Division
California Air Resources Board

November 3, 2016

Outline

- Heavy Duty Diesel Vehicles in California
  - The need for NOx reduction
  - Emission contribution
  - Importance of emission controls under low load/low speed conditions
- California Emission Modeling
  - Zero mile rates
  - Deterioration
  - Speed Correction Factors
  - Vehicle activity
- Efforts to Improve HD Diesel Truck Emissions Modeling in EMFAC2017
- Low NOx Regulatory Support

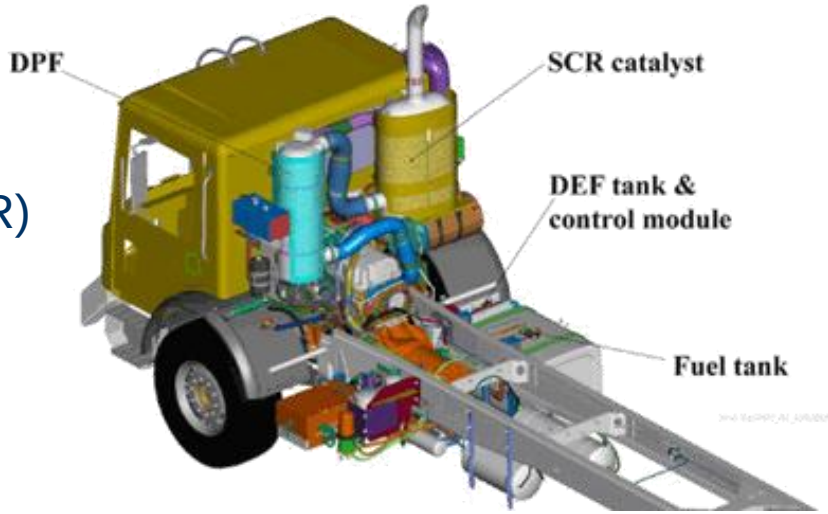
Heavy Duty Diesel Vehicles in California

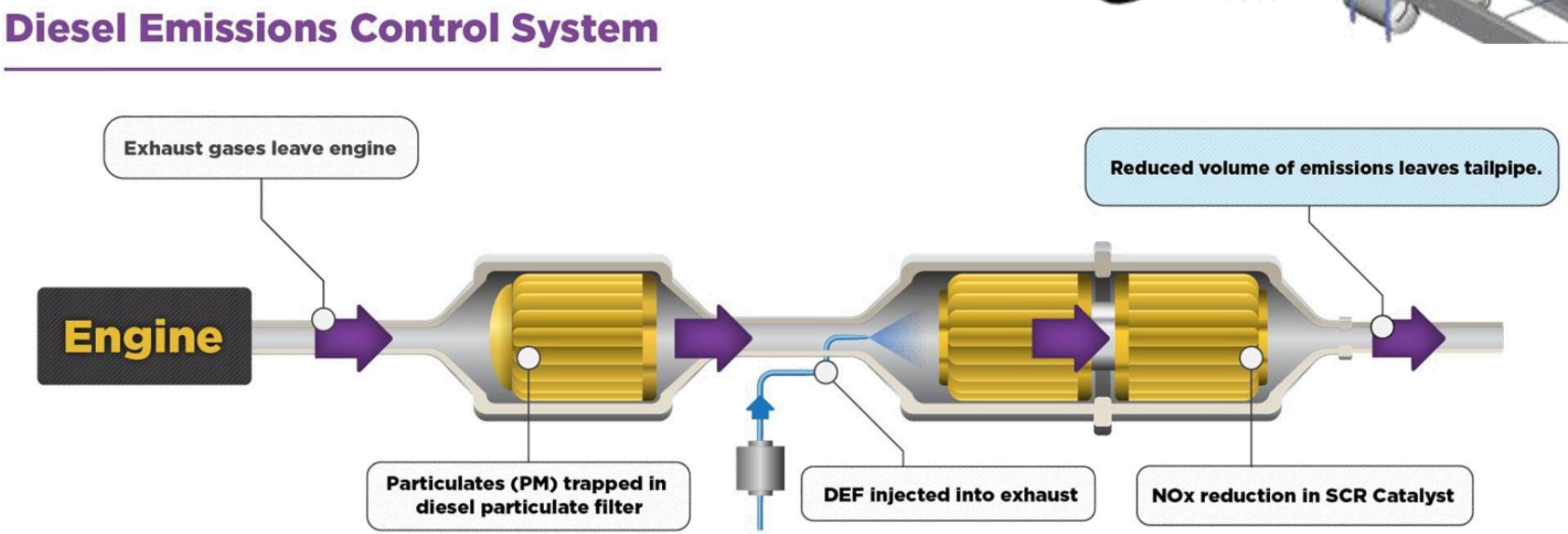
http://www.arb.ca.gov/planning/sip/2016sip/2016statesip.pdf

- Reaching Federal ozone standards in 2031 requires an 80 percent reduction in NOx emissions from today.
- Heavy-duty trucks over 8,500 pounds are currently responsible for about 33 percent of total statewide NOx emissions (all sources)
- A *National Heavy Duty Low NOx Engine Standard* can reduce NOx emissions from heavy duty vehicle (>8,500 lbs. GVWR) by approximately 30% in 2031.
  - A California-Only standard can only reduce emissions by 14%.

Aftertreatment Technologies Used to Meet Today's 2010 Engine Standards

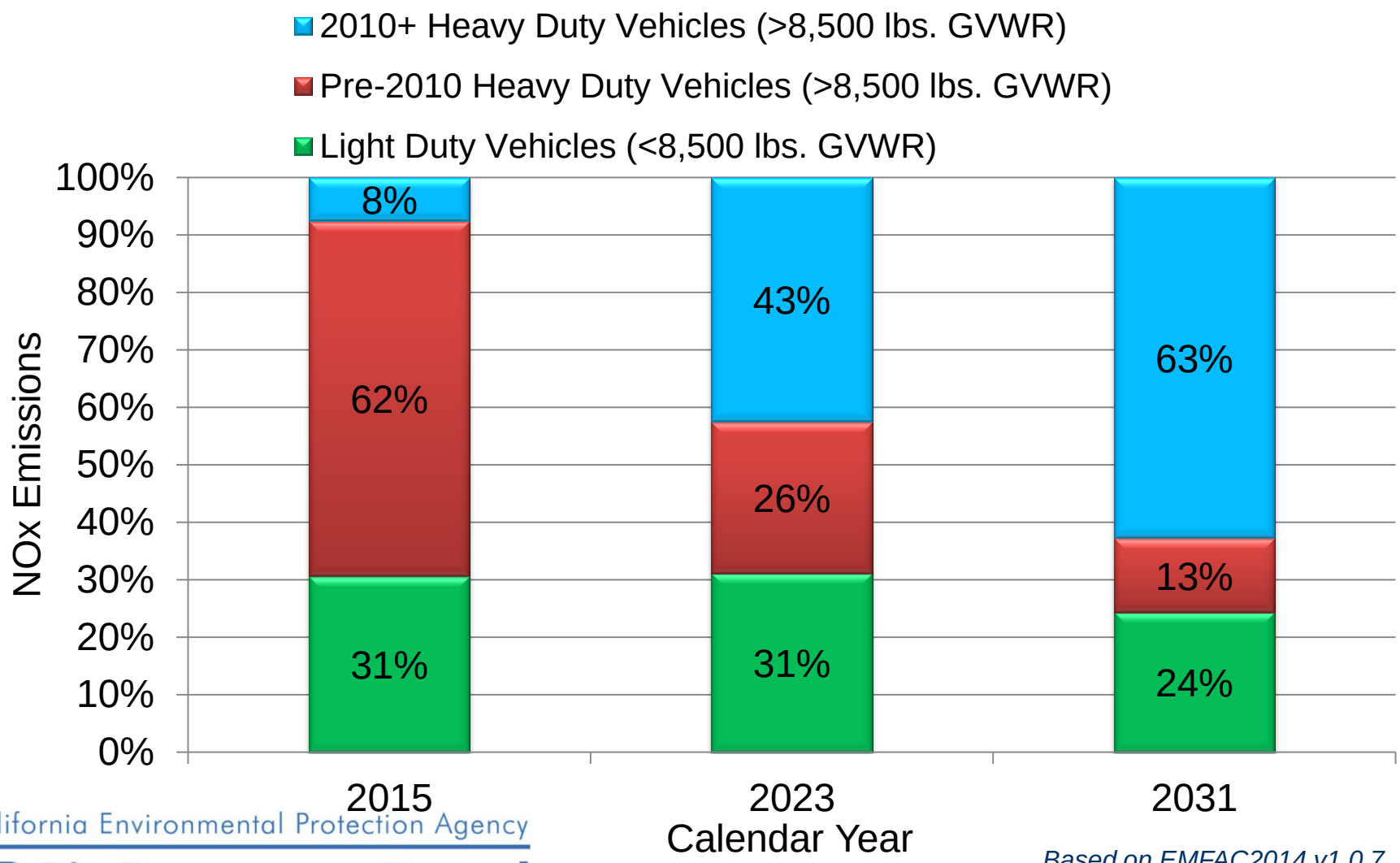
- Current standard:
  - NOx: 0.20 g/bhp-hr
    - Selective Catalytic Reduction (SCR)
  - PM: 0.01 g/bhp-hr
    - Diesel Particulate Filter (DPF)





Reference: http://www.dieselforum.org (modified)

Heavy Duty Vehicles in California (Above 8,500 lbs. GVWR)



Based on EMFAC2014 v1.0.7

All fuel types are included – Gasoline, Diesel, and Natural Gas

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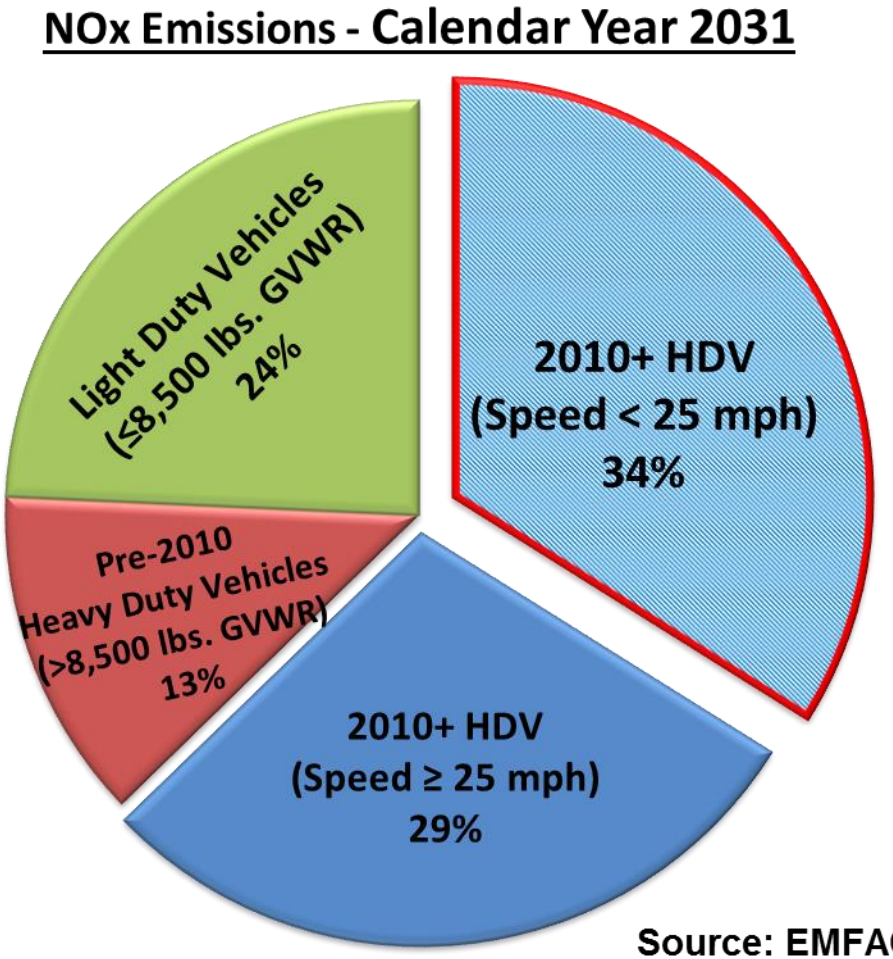

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Emission Modeling

Modeling emissions from heavy duty vehicles consists of four major components:

1. **Zero-mile emission rate (ZMR)** – Fleet average UDDS emission rates while trucks are new
2. **Speed Correction Factors (SCF)** – A method to correct emission factors at different driving speeds (i.e., duty cycles)
3. **In-Use Emission Deterioration (DR)** – Increase of emissions over time within the in-use fleet caused by tampering, malfunctioning, and mal-maintenance of engine components, and emission control systems
4. **Activity** - Metrics of vehicle operation such as vehicle miles traveled (VMT), hours of idling, number of trips, etc.

Emissions (tons/day) = Emission Rate x Activity

Emission Rate (g/mi) = (ZMR + DR x Odometer) x SCF

In-Use Emission Measurements

- In-use vehicle emission testing is a key to ARB's emission inventory development
- In-use trucks are tested on a chassis dynamometer over six different cycles

Test Cycle/Mode	Average Speed (mph)	Duration (sec)	Length (mi)
UDDS	**18.8**	**1063**	**5.55**
Creep	1.8	253	0.12
Transient	15.4	668	2.85
Cruise	39.9	2,083	23.1
High Speed Cruise	50.2	757	10.5
Idle	0	600	N/A

- ARB is also deploying PEMS to measure real-world emission rates

Zero Mile Emission Rates

Running Emission Rates

- Emission rates based on test data collected over UDDS cycle
- Test results back-projected to "zero-mile" using emission increase rates
  - For example if test data is collected from trucks with 60,000 miles, results are back-projected to estimate emissions rates for trucks at zero miles (i.e., zero mile emission rate)
- For 2007-2012 model years, zero-mile rates weighted by sales fractions of different certification levels

Idle Emission Rates

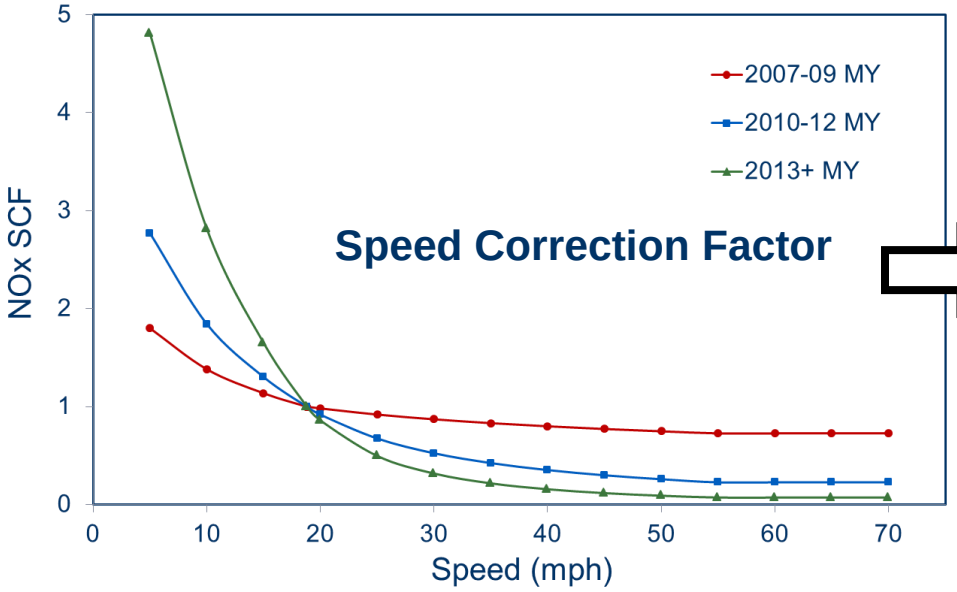
- Based on test data collected over idle cycle and corrected for different accessory loads

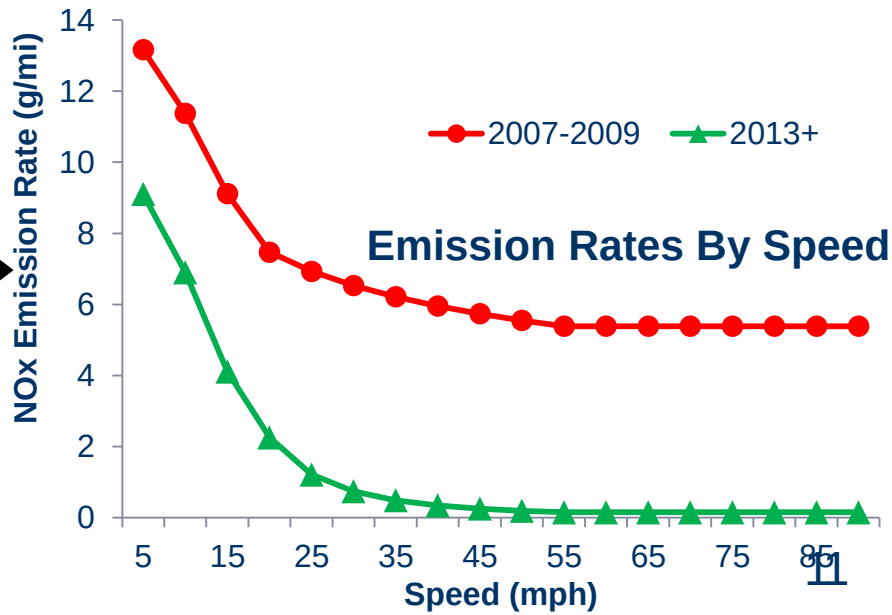
Start Emission Rates

- Derived from on-road PEMS test data

Speed Correction Factors

- HD trucks are driven under a variety of different duty cycles depending on their vocational usage (line-haul vs. last mile delivery)
- Modeling emissions from trucks requires emission rates at different vehicle speeds
- Emissions associated with different driving cycles (i.e., speeds) are estimated using Speed Correction Factors (SCF)
- Speed correction factors in EMFAC are ratio of emission rates at other speeds relative to emission rate at 18.8 mph (UDDS)





Emissions Deterioration

(Engine Component and Emission Control System Failure)

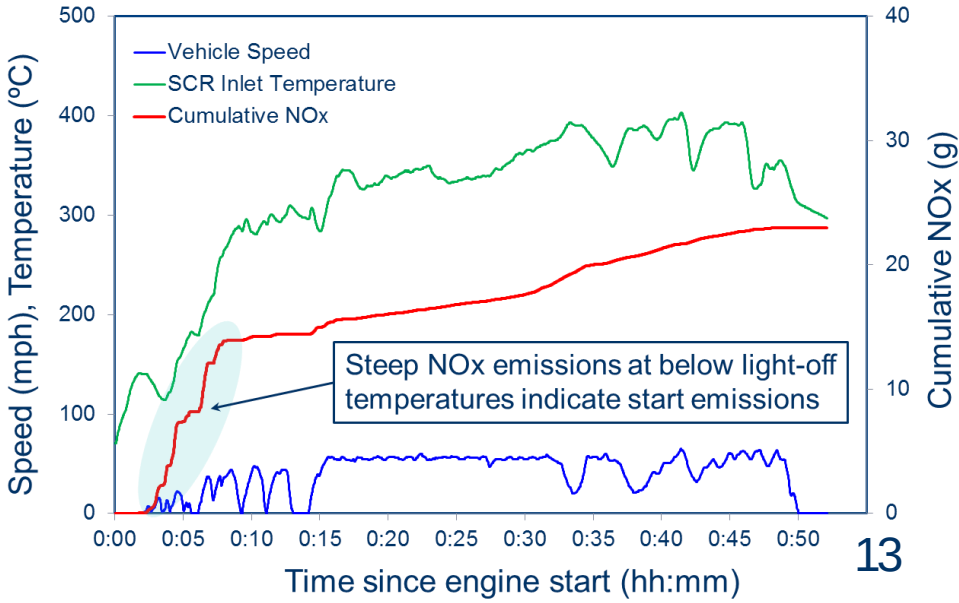
- Emissions increase over time
- For diesel engines, deterioration is caused by
  - Natural degradation of after-treatment systems
  - Tampering and mal-maintenance (T&M)
  - Component malfunction
- Deterioration rates are modeled as a function of
  - Frequency of engine tampering and malfunction
  - Emissions impact of tampering and malfunction

Model Year	2007-09 (DPF)	2010-12 (SCR/DPF)	2013+ (SCR/DPF/OBD)
NOx Emission Increase over 1M Miles	113%	312%	220%

2010+ HDV Start Emissions

- SCR effectiveness is highly temperature dependent.
- 'Start' emission levels are produced before the SCR catalyst reaches its working temperature
- For EMFAC2014, cold/warm start emissions are derived from on-road PEMS testing data
- Start emissions are modeled using:
  - Emission rate per start (g/start)
  - Number of starts per day

Start Emissions (g/day) =
Cold Start ER x # of Cold Starts +
Warm Start ER x # of Warms Starts



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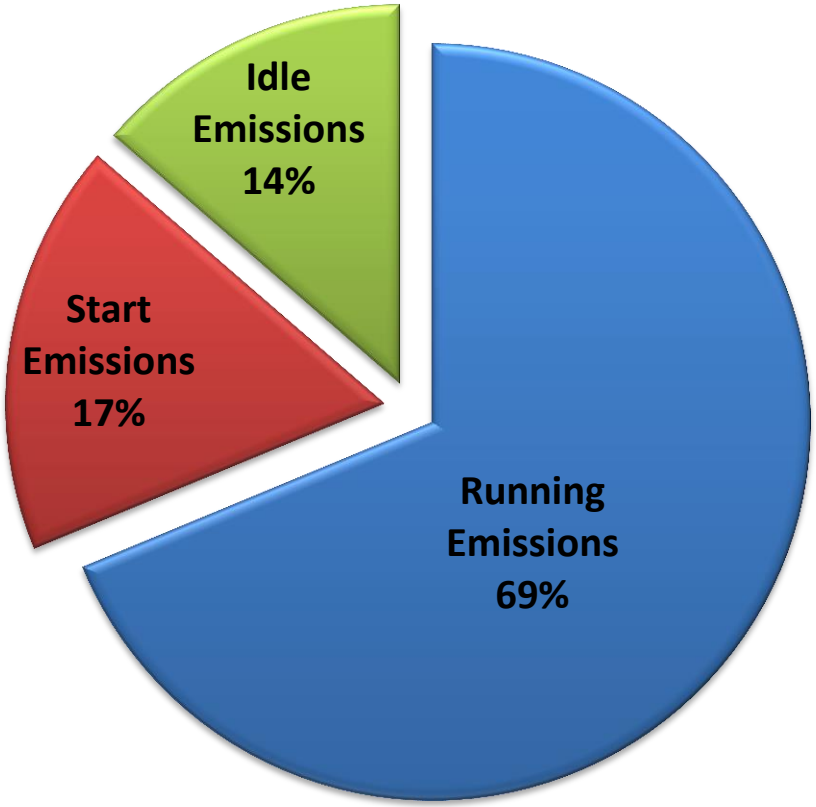
Heavy Duty Vehicle Activity

- Truck and Bus populations are based on:
  - Department of Motor Vehicles (DMV) Registration
  - International Registration Plan (IRP)
- Mileage accrual rates (VMT per vehicle) based on 2002 Vehicle Inventory and Use Survey
- Number of starts and soak time distribution
  - GPS and Telematics data collected through contracted studies
- Fleet turnover accounts for the impact of ARB's in-use regulations such as:
  - 2014 Truck and Bus Rule
  - Statewide Drayage Truck
  - Solid Waste Collection Vehicles
  - Public Agencies and Utility (PAU)

Modeled NOx Emissions in 2031
2010+ Heavy Duty Diesel Trucks (Above 33,000 lbs. GVWR)



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Efforts to Improve HD Diesel Truck Emissions Modeling in EMFAC2017

- Dyno testing of late model HD trucks
- Truck & Bus Surveillance Program
- PEMS testing of late model HD trucks
- Contracted field studies (e.g., RSD, Tent study)
- Deterioration rates updates
  - Frequencies of tampering and mal-functions
  - Emission impact rates
- Collaborating with industry partners (e.g., Cummins Inc.)
- ARB/Cummins emission inventory workgroup

Low NOx Regulatory Support

- EMFAC model will be used to assess emission benefits associated with *Low NOx standards*
- Similar to other ARB's regulatory efforts, EMFAC model will be updated based on latest available data to support this regulation.
- Staff is currently seeking inputs related to available data sources on:
  - Low NOx diesel and CNG engines
  - Heavy duty truck emission deterioration

Contact Information

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California Air Resources Board

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